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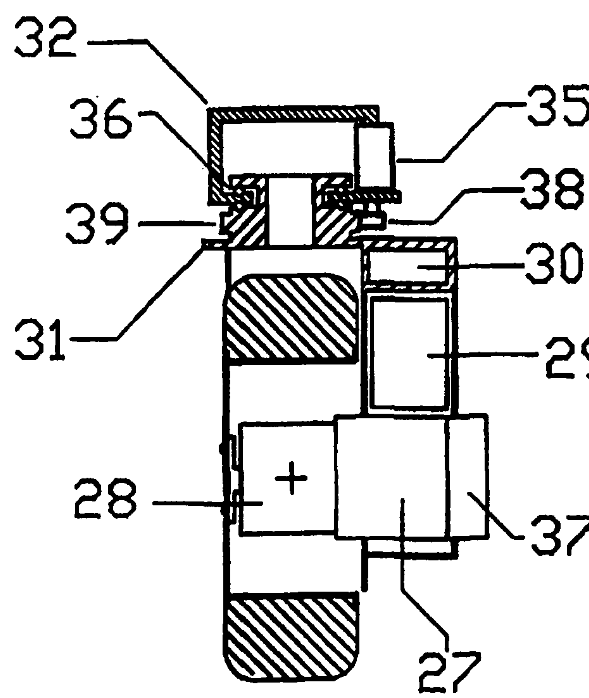
(54) Title: A MODULAR WHEEL ASSEMBLY

(57) Abstract

A self contained powered steerable modular ground wheel assembly has a drive motor, a steering motor, batteries, and computing means fitted in the wheel. An electric vehicle can be fitted with any number of such wheel assemblies which are controlled by a master computer which activates the drive and steering motor in each assembly. The vehicle can thus be steered without any mechanical steering link, and is much more stable by having many of the heavy components in the wheel assembly and thus below the vehicle suspension.



TITLE

A MODULAR WHEEL ASSEMBLY

FIELD OF THE INVENTION

This invention relates to a wheel assembly and in particular relates to a self-contained vehicle wheel assembly containing a drive motor, and an energy storage system (for instance batteries) such that the wheel assembly is self contained, self driven and can be under the control of a computer and its associated software in the vehicle.

BACKGROUND ART

Electrically driven ground wheels are known, and with improvements in battery technology and electric motor efficiency, electric vehicles are becoming more common.

To date, electric vehicles consist of a vehicle body, a number of ground wheels (usually 4), electric motors to drive at least some of the ground wheels, and batteries to power the vehicle.

It is known to have the front or rear wheels of a vehicle driven by electric motors. In one known version, a single electric motor drives a conventional propeller shaft through a differential to power the rear wheels. In another known version, electric motors are positioned adjacent each rear wheel and drive the wheels through suitable mechanical couplings.

In both the above arrangements, the batteries are supported by the vehicle chassis and in order to provide sufficient range, the battery weight is quite considerable.

Attempts have been made to improve the vehicle wheel grip on the road by using a computer-controlled system which varies the speed of rotation of each wheel.

For instance, European patent application 576947 discloses a driving system for a 2 or 4 wheel drive electric motor vehicle. Each driving wheel is coupled to its own motor which is a polyphase asynchronous motor. The motors of each driving wheel are connected to a central electric supply source consisting of batteries mounted on the vehicle chassis. The central electric

supply source produces a polyphase current having a voltage and a frequency which are variable by pulse width modulation under the control of an electronic regulating device. This device receives as imputs, on the one hand, set-value traction signals and set-value breaking signals, and on the other hand, a signal representative of the polyphase supply current and a set of frequency signals each of which comes from a respective sensor and represents the instantaneous speed of the drive motor and of the wheel associated with the drive motor. The device processes the input signals to deliver to a central supply to control signals which define respectively the frequency and the amplitude and thus the effective voltage of the common supply of the motors.

When a vehicle turns a corner, one of the wheels rotates faster than the other of the wheels and thus one of the frequency signals is selected by a processing unit as a reference signal to be used for regulating by a control unit whereas the other signal remains unused. The highest frequency signal is selected so that regulation for all the drive motors (and therefore rotation of the wheels) is effected by considering only the fastest rotating motor and wheel.

This arrangement provides a simple, reliable electric braking mode and also minimises slipping of the wheels by detecting the differential rotation speed and sending appropriate signals to the drive motors to speed up or slow down.

Australian patent application 10185/97 improves on the European patent application by providing further sensors and feedback devices to prevent the driving wheels racing in the event of skidding in drive mode.

There are several disadvantages with the arrangements in known electric vehicles. One disadvantage is the weight of the batteries or other power sources. The batteries are located on the vehicle chassis, and therefore add to the weight that must be carried by the suspension, thereby increasing the possibility of skidding and losing control.

Another disadvantage with existing electric vehicles is that the driven wheels are powered from a central power source. Thus the wheels are not fully self contained and should a fault occur with the central power source,

the vehicle stops.

Another disadvantage with existing electric vehicles is that to date there has been no simple and effective alternative to the current steering mechanism which requires a conventional type mechanical steering link to the wheels. While these mechanical steering links are well known and reliable, the mechanical link to the steering wheels restricts the turning range of the wheels (for instance the wheels cannot turn 90°), and mechanical steering links makes it difficult or impossible to steer each wheel at a unique angle.

Another disadvantage with electric vehicles is that the electric motor is often positioned some distance away from the wheel and is connected to the wheel by a drive shaft. This again presents limitations to the wheel and also puts additional weight above the vehicles suspension system.

A further disadvantage with existing electric vehicles relates to electromagnetic compatibility (EMC). It is a legal requirement in many countries to maintain electromagnetic radiation emission levels as low as possible. Electric devices and particularly motors and electric supply lines emit electromagnetic radiation sometimes at unsafe levels.

OBJECT OF THE INVENTION

It is an object of the invention to provide a wheel assembly and various components which can overcome some of the above mentioned disadvantages or provide the public with a useful commercial choice.

It is a further object of the invention to provide a method of steering a vehicle without requiring a mechanical steering link.

It is a further object of the invention to provide a suspension assembly to which the wheel assembly can be attached.

It is a further object of the invention to provide a vehicle having at least one said wheel assembly.

These and other objects will become apparent in the description of the invention given hereunder.

In one form, the invention resides in a wheel assembly which has a ground engageable wheel, a first drive means to rotate the wheel, a second drive

means to steer the wheel, an energy storage device to at least partially supply the drive means, and a attachment means to attach the wheel assembly to a vehicle.

In another form, the wheel assembly is controlled by a computing means, for instance, to control the speed and direction of the wheel.

In another form, the invention resides in a method for steering a vehicle having one or more of the above wheel assemblies by controlling the speed of rotation of the wheel assemblies, for instance using a computer means.

In a further form, the invention resides in a suspension assembly to which the wheel assembly as described above is attached.

In a further form, the invention resides in a vehicle having a least one said wheel assembly and optionally the said suspension assembly and steering method.

By having the wheel assembly in a self contained unit, or modular system, the assembly can be removed from the vehicle should a fault occur, and repaired, or replaced with a new wheel assembly. This makes maintenance of electric vehicles having such a wheel assembly easier and quicker.

By having the wheel assembly containing, as a unit, the wheel itself, the first drive means to drive the wheel, the second drive means to steer the wheel, and a power supply (for instance batteries) to power the drive means, much of the weight which otherwise would be above the vehicle suspension is now below the vehicle suspension giving better traction and road handling properties to the vehicle.

Further, by having the components close together in the wheel assembly, the electromagnetic radiation levels are substantially reduced compared to existing electric vehicles.

An electric vehicle having, for instance, four of the wheel assemblies can continue to function should one of the wheel assemblies fail, as the other wheel assemblies being independently powered will continue to drive the vehicle.

By having a wheel assembly as described above, more versatility

is possible with the suspension assembly and the steering arrangement. For instance, as the wheel assembly need not have any mechanical drive links to the vehicle, the suspension assembly can be used to increase or decrease vehicle ground clearance in a simple yet reliable manner.

It is also possible for the wheel assembly to steer or pivot through a larger range than hitherto possible with a mechanical steering link. For instance, the second drive means can form part of the wheel assembly and can steer or pivot the wheel possibly through 90°, 180° or even greater turning angles. This in turn allows the vehicle to turn through tight corners and park in narrow areas.

The wheel assembly can be used on a number of electric type vehicles including cars, buses, trucks, road trains, lorries, military vehicles, aircraft, helicopter and spaceship wheels, but also including one, two or three wheeled vehicles, wheelchairs, self propelled devices and the like. The invention is suited for vehicles requiring a large number of wheels which can be fitted in a regular or irregular manner.

The wheel of the wheel assembly can be sized and shaped to suit the particular vehicle on which the wheel assembly will be used. The wheel can have a central hub and a peripheral tyre, for instance a pneumatic tyre. Solid wheels or composite wheels are also envisaged for other applications.

The wheel assembly can have more than one ground engageable wheel and this may be required for extra grip or to support heavier loads. However, it is preferred that the wheel assembly consists of a single ground engageable wheel, and if heavier loads are to be supported, a greater number of wheel assemblies can be fitted.

The power supply preferably forms part of the wheel assembly which reduces electromagnetic radiation levels by having the power supply close to the drive means and also removes weight from above the suspension to below the suspension. The power supply can consist of one or more batteries or other types of power supply devices. If necessary, these can be topped up or supplemented from an external supply, for instance by solar cells on the vehicle,

fuel cells, and the like.

The drive means is typically an electric motor although it is envisaged that a hydraulic motor could also be used in some circumstances. A gearbox or gear train or transmission of sorts can be provided to couple the electric motor to the ground wheel.

The second drive means can also consist of an electric motor which can be powered by the same power supply. The second drive means functions to steer or pivot the wheel.

The wheel in the wheel assembly can be steered in a number of ways. One preferred way is to have the wheel supported by a first support or frame, which can pivot relative to a second support or frame, with the second support or frame attached to the vehicle (typically via the vehicles suspension). The second drive means can cause the first support or frame to pivot relative to the second support or frame.

More particularly, the ground wheel can be supported within an inner ring that rotates within an outer ring. The outer ring is attachable to the vehicle, for instance to the vehicle suspension. The second drive means rotates the rings relative to each other which in turn pivots the ground wheel. With this arrangement, the ground wheel can, in principle, pivot through 90°, 180° or even through larger angles if desired (which is difficult or impossible with a mechanical steering link).

In another form, the ground wheel forms part of an inner frame which is pivotally attached to an outer frame, and where the second drive means can pivot the inner frame relative to the outer frame, with the outer frame being attached to the vehicle.

By having the wheel assemblies being individually steerable, another form of the invention is a method for steering a vehicle containing at least some of the wheel assemblies as described above.

The motion of a vehicle at any instance can be analyzed as travelling an arc of a circle. When a vehicle travels along an arc of a circle the inner wheel (that is the wheel closer to the center of the circle) rotates slightly

slower than the outer wheel. Therefore, the wheels turn at a speed, which is proportional to the distance of that wheel from the center of the circle.

By using polyphase electric motors as the first drive means in the wheel assembly, the rotation of the electric motor can be controlled by semi conductive circuitry such that the speed of rotation of the electric motor is controlled by a master control computer or other computer circuitry as may be necessary.

For instance, the master control computer can vary the frequency of the alternating current wave forms applied to each phase of the polyphase electric motors which preferably form the first drive means of the wheel assembly and that the speed of the multiphase motors is a function of the frequency.

In this manner, a central computer can accurately increase or decrease the speed of rotation of the ground wheel of each wheel assembly and this is a simple and reliable method to steer a vehicle without requiring a mechanical steering link.

The vehicle wheels can be controlled such that each wheel is tangential to a circle, the center of which is the same position as, the center of the circle, of which the vehicle is traveling an arc.

A steering angle sensor can be used as part of a feedback loop to achieve the desired steering accuracy.

The electric system used in the wheel assembly and the vehicle to which the wheel assembly is attached can include wires, cables, conductors, components such as fuses, circuit breakers, diodes, other semi conductor devices, transformers, coils, capacitors, resistors, and other arrangements used to distribute the electric supply.

It is preferred that a low voltage direct current is used, and a typical voltage is from 12 volts up to 60 volts or more.

The electrical system supplies electric power to the various electric and electronic components, computers, electric motors, sensors, electric actuators, and various circuits which distributes the electric supply throughout the vehicle, its modules, attachments, accessories and the like.

Instead of a direct current, a low voltage alternating current system may also be used. This has the advantage of being able to couple and transfer electric energy into parts of the electric vehicle, its modules and attachments without direct electrical or mechanical contact. Alternating current could for instance use inductive or capacitive coupling to transfer electric power to moving or pivoting parts.

If an alternating current system is used, this may be single phase or multi phase. It is preferred that an alternating current system is of relatively low voltage having a root mean square of 32 volts or more. A typical frequency of the alternating current would be between 400Hz to 1000Hz although other frequencies are envisaged.

The first drive means and second drive means in the wheel assembly suitably comprise electric motors. It is preferred that the electric motors are low voltage, multiphase electric motors having a voltage typically up to 60 volts or more.

The motors can be conventional polyphase induction motors wound for low voltage operation. The motors could include polyphase stepper motors, brushless DC motors or polyphase synchronous electric motors.

If polyphase induction motors are used (these being preferred), the voltage and current wave forms to drive the phases of these motors are produced by use of semi conductive devices and components in conjunction with normal passive components such as resistors, capacitors and inductors. The circuitry typically includes additional components to further facilitate the regenerative braking capability of the circuitry of the associated low voltage polyphase electric motors.

The circuitry can also contain micro processes or micro controllers required to produce the various wave forms such that the associated low voltage polyphase electric motors perform as required.

The circuitry with its micro processes and micro controllers are preferably mounted within or adjacent the electric motor (and preferably within a metre from the electric motor). This allows the wheel assembly to be more or

less a self-contained unit and also can reduce the electromagnetic radiation emission levels.

The use of low voltage polyphase electric motors are preferred because, as these motors can provide accurate speed control within close limits, fewer battery cells are required to provide the voltage required by the motors, the low voltage motors are safer to work with, and supplementary top up power supplies such as solar power can be more easily used to provide a low voltage top up to the battery.

The power supply preferably comprises one or more batteries. These can be supplemented by additional power supplies such as solar cells, fuel cells, booster batteries, connection to other electric vehicles, connection to an external source of electric energy and the like.

In a further form of the invention, a master control computer is provided to control the pivoting of the wheel in each wheel assembly and the speed of rotation of the wheel in each wheel assembly. The master control computer can process signals from various sensors to provide real time specification of speed and direction of each wheel assembly. With the improved suspension arrangement, the master control computer can also be used to vary the height of the vehicle above the road.

Another form of the invention is a suspension assembly, to which the wheel assembly as described above, is attached.

In one form, the suspension assembly can be a controlled leading trailing torsion arm arrangement. This arrangement can control the position of the arm to alter the height of the suspension. It can control the position of the arm (from trailing to leading and vice-versa) to alter the wheelbase of the vehicle. It can control the position of the arm to allow the vehicle to climb obstacles. When in either of its high of low height modes, it provides a relatively soft suspension. When in its highest position it provides a relatively harder suspension relative to the lower mode. The arrangement allows a particular wheel assembly to be lifted clear off the ground to allow the wheel assembly to be inspected, serviced or replaced. It is envisaged that an emergency stop

arrangement can be used where the height of the vehicle is reduced such that some special baking device comes into contact with the road surface and assist in the braking process.

BRIEF DESCRIPTIONS OF THE DRAWINGS

Figure 1 is a section view of a wheel assembly according to a first embodiment of the invention.

Figures 2A – 2E illustrate various views of a wheel assembly according to a second embodiment of the invention.

Figures 3A – 3E illustrate various views of a more robust wheel assembly according to a third embodiment of the invention.

Figures 4A – 4C illustrate a variable height suspension arrangement according to a first embodiment of the invention.

Figures 5A – 5C illustrate a variable height suspension arrangement according to a second embodiment of the invention.

Figures 6A and 6B illustrate a mechanical steering linkage with selective overdrive.

Figure 7 illustrates, in plan, an electric vehicle having four wheel assemblies.

Figure 8 is a side view of the vehicle of Figure 7.

Figure 9 is a front view of the vehicle of Figure 7.

Figure 10 illustrates the connection of the wheel assemblies to the master computer.

BEST METHOD OF PERFORMING THE INVENTION

Referring to the figures, and initially to Figure 1, there is illustrated, in section, a wheel assembly 10 according to a first embodiment of the invention. Wheel assembly 10 is self-contained unit, which can be bolted to and unbolted from a vehicle suspension arrangement. Assembly 10 contains a peripheral pneumatic tyre 11 attached to a metal rim 12, with rim 12 being bolted or otherwise attached to a central metal hub 13. The arrangement provides an internal cavity which has been used to house the various other components of the wheel assembly. Thus within the cavity is provided a power supply in the

form of one or more batteries 14 which provide power to a low voltage polyphase motor 15. Immediately behind polyphase motor 15 is a polyphase inverter and controller 16 which is connected to the power supply, and this arrangement is cooled by a cooling fan 17 which also provides a positive pressure within the entire cavity to minimise intake of dust and road debris. Polyphase motor 15 has an output cog or pulley 18 about which is fitted a belt drive 19 which extends about a second pulley or cog 20 which is attached to hub 13. In this manner, motor 15 drives the vehicle wheel.

A disk brake assembly is provided within the wheel assembly, which consists of a circular disk plate 21, which can be gripped by a pair of relatively moveable disk brake pads 22 as is known in the art. This provides a mechanical braking of the wheel.

Referring to Figures 2A – 2D, there is illustrated a compact wheel assembly 24 suited for general use across a wide variety of applications from road, industrial, agricultural and military.

Assembly 24 is shown in side view in Figure 2A and in section view in Figures 2B and 2D, and again consists of a ground engageable wheel 25 fitted to a hub 26. Better illustrated in figures 2B and 2D, a first drive means in the form of a polyphase low voltage electric motor 27 is positioned at least partially within the internal wheel cavity and is coupled to a gearbox or drive train 28. One or more batteries 29 power motor 27 via the polyphase inverter 37 and the speed of the motor is controlled by a control computer 30.

Wheel 25, motor 27, batteries 29, gearbox 28, inverter 37 and computer 30 are supported together on an inner frame 31. Inner frame 31 is pivotally coupled to an outer frame 32 better illustrated in Figure 2E. In turn, outer frame 32 is attached to a vehicle suspension arrangement 33 through attachment pins 34.

The wheel and the inner frame 31 can be pivoted and therefore steered relative to outer frame 32 via a second drive means in the form of a steering motor 35 which has an output cog 38 which engages with main cog 39 which in turn pivots frame 31 on bearing 36.

Therefore, by controlling the speed of rotation of steering motor 35, the wheel can be steered relative to the vehicle.

Figure 2C shows wheel assembly 24 mounted to a suspension arrangement 33 via attachment pins 34. It can be seen that the wheel assembly does not have a mechanical drive shaft to the vehicle (the drive being conducted by electric motor 27 in the wheel), nor does wheel assembly 34 have a mechanical steering link to the vehicle (the steering being achieved through steering motor 35).

Figures 3A – 3C illustrate a more robust wheel assembly suited for off road vehicles, aircraft, agriculture and military uses. Figures 3A and 3B show side and end views of the wheel assembly and Figure 3D shows the wheel assembly attached to a suspension arrangement. Figure 3C is a plan, partially section view of Figure 3B, while Figure 3E is a plan, partially section view of Figure 3D.

Wheel assembly 40 of the third embodiment illustrated in Figures 3A – 3E again consists of a ground wheel 41 which sits within a strong steel outer support ring 42. Outer support ring 42 is attached to a suspension arrangement 43 in a manner similar to that illustrated in Figures 2A – 2D and again through attachment pins 44.

Figure 3C illustrates some of the internal components, which again consist of a polyphase electric motor 45, and a larger number of batteries 46 (there being considerably more space available for batteries inside the rather larger outer support ring 42). Motor 45 is connected to gear box or gear train 47 which drives wheel 41 in a manner similar to that illustrated in Figure 1 and Figures 2A – 2D.

Inside outer support ring 42 is also located the control computer 48 which has the advantage of making the wheel assembly more or less fully self contained and modular.

Referring to Figure 3C, the wheel, electric motor 45, all the batteries 46, the gearbox 47, and computer 48 are supported by an inner support ring 49. Inner support ring 49 can rotate relative to outer support ring 42 thereby

allowing the vehicle wheel to steer or pivot. The steering is achieved by a electric steering motor 50 which is fixably mounted to outer support ring 42 and which rotates inner support ring 49 relative to the outer support ring via a large circular bearing 51 which sits between the two support rings.

Figures 4A – 4C illustrate the height adjustability of the vehicle chassis relative to the wheel assembly. Referring initially to Figure 4A, a wheel assembly 52 identical to that described with reference to Figures 3A – 3E is attached through attachment pins 44 to a suspension arrangement 43. Suspension arrangement 43 is a type of parallelogram type linkage arrangement consisting of a pair of parallel suspension arms 53, 54 which are pivotally coupled at one end to attachment pins 44, and are pivotally coupled at the other end at spaced positions against a suspension member 55 which is bolted to vehicle chassis 56. A ram 57 is attached at one end to member 55 and at the other end to arm 54. Extension and retraction of the ram causes chassis 56 to rise or fall relative to wheel assembly 52.

Referring sequentially from Figures 4A to 4C, it can be seen that vehicle chassis 56, in the position of Figure 4A is extremely low, while in the position in Figure 4C has been lifted quite high above the road. A computer in the vehicle controls extension and retraction of ram 57.

Figures 5A – 5C illustrate a suspension arrangement according to a second embodiment of the invention which can be used with the wheel assembly illustrated in Figures 2A – 2D.

In this arrangement, various pulleys and ropes are used to achieve the correct orientation of the wheel assembly relative to the vehicle chassis.

In particular, there is again illustrated a wheel assembly 60 consisting of a ground wheel 61. For the sake of clarity, the internal components of wheel assembly 60 are not illustrated, but these include the electric motor, gear box, batteries and the like. Wheel assembly 60 has a wheel support frame 62, and an upper frame 63 which pivots relative to frame 62 which in turn can cause wheel 61 to steer (a steering motor is used to pivot the members but has not been shown for reasons of clarity). Upper frame 63 is pivotally attached to a

first arm member 64 which is itself pivotally attached through main pivot point 65 to a backing member 66 which can be bolted to the vehicle chassis. A fixed pulley 67 is positioned behind main pivot point 65 and is rigidly mounted to a backing plate 66. A line member such as a wire rope or belting 68 extends about fixed pulley 67 and a far pulley 69, this pulley being rigidly attached to a shaft which is rigidly attached to upper frame 63. An electric or hydraulic motor 70 drives gears 71 – 73 to rotate first arm member 64 about main pivot point 65.

Figures 6A and 6B illustrate two versions of a mechanical steering linkage with selective over ride which can over ride the computer controlled steering.

Referring to Figures 6A and 6B, there is illustrated in side section view a wheel assembly 90 where the steering of the wheel can be done mechanically should for instance the steering motor fail. Referring to the figures, wheel assembly 90 again has an internal drive motor (not shown) and an internal battery pack (not shown). The ground wheel 92 of assembly 90 is rotatably attached relative to a circular plate 91 which has an inverted T-shape configuration such that cooling air 93 can pass into the interior of plate 91 for cooling. Plate 91 is attached to the top portion 94 of wheel assembly 90 via main bearings 95 which allows wheel 92 to turn or pivot. Top portion 94 is formed from metal structural members which are attached to the vehicle suspension arms 96. This is analogous to the way that the wheel assembly of Figures 2 and 3 are attached to the respective suspension arms.

Rigidly attached to the T-shaped portion of plate 91 is a bevel gear 97. Rotation of bevel gear 97 causes plate 91 to pivot which in turn steers wheel 92. Bevel gear 97 is rotated by a intermeshing smaller bevel gear 98. Bevel gear 98 is attached to a shaft 99 which terminates in a large circular circumferentially toothed gear 100. Gear 100 is rotated by an electric motor 101 which has an output cog 102 which meshes with the circumferential teeth on gear 100.

Thus, activation of motor 101 to rotate its cog 102 will in turn rotate gear 100 either clockwise or anticlockwise as is desired. Rotation of gear 100

rotates shaft 99 which rotates bevel gear 98 which in turn rotates bevel gear 97 which, because of its rigid attachment to plate 91, causes plate 91 to turn which in turn steers wheel 92.

The arrangement in Figures 6A and 6B have a mechanical override whereby the wheels can be steered mechanically if desired. For instance, should motor 101 fail, it may be necessary to have a mechanical override. Alternatively, it is possible that many countries will insist upon some form of direct mechanical steering.

In Figures 6A and 6B, this is achieved by a second shaft 103 one end of which is attached to a pulley or like member 104 which forms part of the mechanical steerage linkage further details of which are not illustrated. Shaft 103 terminates in a steel plate 105 which locates within large gear 100. Plate 105 has a cut-out section in it in which one end of pawl 106 can locate. The cut-out section is wider than the width of pawl 106.

The movement of pawl 106 is controlled by a cam follower 107 as it follows cam 108. Hence pawl 106 is controlled so as to selectively engage the plate 105. That is the pawl engages plate 105 when the steering is within for instance 20° of central.

Figures 7 – 10 illustrate an electric vehicle according to an embodiment of the invention.

Referring initially to Figure 7, there is shown an electric vehicle in plan. The vehicle has a central rotatable turret 110 which can rotate 180° (or possibly 360°). Thus, instead of reversing vehicle, turret 110 can be simply rotated 180° to always allow the vehicle to move in a "forward" direction. The main master computer is located in a forward portion 111 of turret 110. The vehicle has four wheel assemblies 112 each having its own batteries, drive motor, steering motor and computer. Each wheel assembly is mounted to a suspension 113. The vehicle contains space 114 for a fuel cell, fuel tank or an auxiliary power supply for instance in the form of a small internal combustion engine connected to an alternator. Figure 9 particularly illustrates the desired suspension arrangement which can be pumped up or down by rams 116 to allow

the vehicle ground clearance to be monitored and varied at will (this being much more difficult with mechanical steerage links and the like).

Figure 10 illustrates how the various wheel assemblies 112 are connected via conventional or fiber optic cable 117 to the master computer 118 mounted in the forward part of turret 110.

A master control computer located in the vehicle can control the wheel assemblies. Typically all the wheel assemblies will have a unique address and/or connection to the master control computer. The master control computer will address or feed all these addresses or connections so that all the wheel assemblies and other modules are under its control. The master control computer can interrogate the control panel computer and hence all of the operator controls, for instance the position of the accelerator control, the position of the steering control, the suspension height control and the like.

The master control computer will interrogate each of the wheel assemblies to obtain their status and other data such as the temperature of the motors, the angle of steering, the height of the suspension and the like. The master control computer will also have access to information relating to the energy systems including the status of batteries, solar cells, fuel cells and the like. The master control computer will also have access to navigational information such as road maps, global positioning systems, compass bearings and the like.

The wheel assemblies are steered by signals from the computer to the steering motors in each wheel assembly. This is in contrast with conventional steering where the steered wheels are rigidly controlled through solid mechanical linkages which offer very little in the optimum control of wheels particularly in maneuvering in tight spaces.

In contrast, the wheel assemblies according to the invention offer the flexibility and excellence in steering. For instance the wheel can be steered and speed controlled regardless of the number of wheels on the vehicle. The master control computer can steer and power each wheel many times a second to ensure accurate and responsive control.

For instance, when the vehicle travels in a straight line on a flat horizontal surface, the speed and direction of each wheel is the same. However when the vehicle travels around a curve, all the wheels may be required to turn at different speeds (especially if the road surface also undulates). Additionally, all the wheels may be required to point in different directions to allow the vehicle to travel around the curve correctly with maximum traction and minimum wheel skid. The master control computer attends to this by sending the required signal and individual commands to each of the wheel assemblies.

The vehicle controls in the vehicle contain sensors and associated circuitry which feed the sensor output to a control platform computer which is in turn interrogated by the master control computer on a real time basis. The accelerator and steering controls in the vehicle are continually being interrogated by the master control computer via the control platform computer and this can occur many times per second such that acceleration and steering is smooth and responsive and also has tactile feedback such that the steering wheel feels like that of a conventional vehicle. The vehicle itself can be fitted with a cabin or turret which can rotate through 360°. The master control computer is programmed such that the turret can be rotated into any angle and the master control computer is reoriented such that the direction in which the turret is now facing becomes the forward position of all controls and the wheel assemblies are reoriented accordingly. In this manner, the term "reverse" no longer becomes applicable as the driver merely rotates the cabin to face in the direction of travel.

The drive motors in each wheel assembly produce the torque and/or the linear actuation as specified by the vector in the vector control data which is unique to the wheel assembly and receive from the master control computer.

That is, the purpose of the electric motor is to cause the wheel assembly to move at the speed specified by the vector in its vector control data received from the master control computer located in the main structural frame of the vehicle.

All wheel assemblies will each move at their individual speeds and

directions as specified by their vector control data received from the master control computer.

It is important to note that, for example, when the vehicle is travelling around a curve, that all the wheels may be turning at different speeds. Also all of the wheels may be pointing in different directions so as to cause the vehicle to travel around the specified arc of the circle, with center of that circle at the specified point.

This is arranged and controlled by the master control computer which sends a unique block of vector control data to each wheel assembly. This is a dynamic process with new data typically being sent and received by each wheel assembly many times per second.

Typically the motors will be located within their wheel or immediately adjacent to it. The motors may be directly connected to the wheel/tracks. However more generally they will be coupled via a gear box and/or belt and pulley and/or socket and chain or combination of these.

Some wheel assemblies will have provision to control the ratio of above as specified by their vector control data.

When fitted to a vehicle, all wheel assemblies will have identical gear change ratios, the changing of gear ratios being controlled from the master control computer, via the vector control data to each wheel assembly.

Each wheel assembly will contain one (or more, for redundancy) steering motors typically consisting of a low voltage multiphase electric motor and controller.

The steering motor or motors are under the control of the vector control computer within this wheel assembly such as to cause it to move in the direction specified by the vector control data which is unique to this wheel assembly, and is received from the master control computer.

Typically each wheel assembly can point its wheel in any direction.

The preferred version is a vehicle with the fully optioned steering, the wheel assembly can turn through a full 360°. This version includes slip rings and brushes and/or other means for electrical power and signals to be passed to

the wheel assembly from the main structural frame via its suspension such that it has unlimited steering freedom, i.e. steer through multiple revolutions.

i.e. the fully optioned steering allows for the wheel assembly to steer through multiple revolutions without any problems. Another steering option is for more than 360°, but not able to steer through multiple revolutions continuously, without a problem, with a programmed finite number of revolutions. I.e. this option would use (at least some) cables, which would eventually cause a warning to appear, before they became too tangled etc.

Hence on occasion it is possible that either the vector control computer would act in such a way as to prevent a tangle developing in the cables. Or alternatively a warning would be issued to the driver to take action to effectively unwind the cables between the main structural frame and the vector wheel module.

Another steering option is slightly more than 180°. While not quite as versatile as the preferred option, it is a less expensive option. However since the direction of the wheel can be changed so easily (even transparently by the vector control computer), this can also offer an effective full 360° of steering.

The least complex and versatile steering option is for steering angles, similar to that of conventional vehicle.

Also note that either by the use of multiphase motors described and the use of additional sensors to measure the angle of the wheel assembly, and appropriate feedback circuitry and/or software/firmware, that the angle at which the wheel points can be held to tight limits.

Also note that reliability increases, and the chance of serious failures is reduced as the total number of phases increases (i.e. the number of steering motors (per wheel assembly multiplied by the number of phases per multiphase motor used).

Each wheel assembly contains one or more (for redundancy) vector control computers.

This vector control computer is the main computer within the wheel assembly and its functions are as follows –

Interface all signals (in both directions) with the main control computer in the main structural frame of this vehicle. That is, receive and send vector control data from/to the main control computer.

Interface with all the motors and other actuators contained within this wheel assembly, (and any associated gear change arrangements (gearbox and/or belt pulley) etc.

Interface with all sensors, that is speed, direction, angle, temperature, pressure etc. and/or the computer/micro contained within or associated with those sensors.

Control the overall action of the wheel assembly in accordance with the vector control data which is unique to this vector wheel module, and is received from the master control computer.

i.e. The main control computer sends vector control data to each of the wheel assemblies.

The vector control computer in that wheel assembly use its vector control data to control the vectoring of its wheel (both speed and direction) and all other functions.

Each wheel assembly (and hence its vector control computer) has a unique address and/or connection to the signal from the main control computer.

The vector control data passing between the main control computer and each wheel assembly can be conveyed via an electric cable (typically 2 or more conductors), via fiber optic cable, via electro magnetic radiation (including radio, microwave, infrared, etc.) or via acoustic waves or via direct electrical inductive or capacitive coupling.

Each wheel assembly will contain a battery or other significant energy storage device capable at least of powering that vector wheel module when operating at full power for at least a few minutes and in most cases for a few hours or longer.

Each wheel assembly containing a battery etc. gives this invention a number of significant advantages –

Lower center of gravity for the vehicle hence better handling,

traction, etc. because most of the batteries and motor i.e. heavy items are located in the wheel assemblies close to the ground.

High peak electrical demands are supplied via short cable runs between the batteries in this wheel assembly and the motors and other actuators within this wheel assembly.

Hence this allows the vehicle to be more efficient, as for any cable with a given cross sectional area there will be less resistance, (because the cable is shorter) and hence less energy loss as the electrical current travels through that cable.

It is particularly important that, the batteries are able to handle high peak current levels. Typically the peak current capacity of these should at least be equal to the maximum DC current drawn with the motor running at full power.

Less weight to be carried by the vehicle suspension hence more comfort and better economy. With the vehicle, because there is less weight on the suspension, it means that the suspension can be constructed with the passengers, etc. in mind rather than having to construct it to carry all of batteries and other heavy equipment.

Electromagnetic compliance regulation are easier to meet because batteries are located in the wheel assemblies, hence the cables between the motors (in particular the traction motor and its inverter) and the batteries are short. Hence these short cables will typically radiate less electromagnetic interference, so making it easier to comply with electro-magnetic regulations of the countries or states in which the vehicle is sold or used.

Typically, in the first instance, all wiring and electronic and electrical components etc. will be insulated from the outer shell of the wheel assemblies. This outer shell (or enclosure) will typically be constructed from metal, or other electrically conductive material or from materials such as plastic or fibreglass etc., but to which has been applied a coating of conductive material etc. so as to form a screen to electromagnetic radiation, and so prevent it escaping from the wheel assemblies and the vehicle.

Typically some of the components within the wheel assembly will

themselves have their own partial or full electrically conductive screen, i.e. the external metal surface of the polyphase motor, in itself forms a screen.

The use of a number of electrically conductive screens, as described above, each of which in the first instance are electrically insulated from each other, allows for the selective bonding (electrical interconnection) of these screens and components to each other, so as to ensure minimal leakage of electromagnetic radiation.

This is also particularly important for sales into certain markets, i.e. military vehicles, also for vehicles used in cities and suburbs where there is wide usages of the electro-magnetic spectrum.

Typically the batteries used will have low electrical impedance, particularly at the frequencies (and their harmonics) used by the motor drive electronics/micros.

Typically each wheel assembly contains a device, (or alternatively the suspension associated with it has a device) for raising or lowering the vehicle. This device is under the immediate control of the vector control computer which is under the control of the master control computer, i.e. the ground clearance of the vehicle can be changed simply by touching a button in the main structural frame, or remotely or roboticly. No mechanical linkages are used to transmit traction power to the wheel assembly. Typically there is only an electrical connection between the main structural frame of the vehicle and its wheel assemblies.

Some countries or states may insist that vehicles have a mechanical steering linkage between the main structural frame and certain (or all) of the wheel assemblies when a vehicle is used under certain prescribed conditions, i.e. on public roads etc.

Because typically there is only an electric cable (which can be very flexible etc. between the main structural frame and the wheel assemblies, it means innovative and different suspensions can be used, i.e. a vehicle can be constructed with a suspension such that the ground clearance under the vehicle can be controlled by the operator (or remotely or roboticly) to vary from zero (i.e.

to change a tyre etc.) to say a few hundred millimetres for good road holding and highway use to a significant part of a metre (or more than a metre) should that be required, i.e. for crossing streams etc.

Vehicles can be constructed to have all the low profile features etc. or a quite city car, for car parking in confined spaces, yet at the touch of a button it can be transformed into high ground clearance vehicle for country or outback use.

Another feature of the invention is the flexibility, maintainability and reliability of a vehicle with multiple wheel assemblies should one or more become damaged or faulty. Then the damaged/faulty assembly can either be put into idle mode or simply removed. Either a spare assembly is fitted or alternatively the remaining good assemblies can be re-distributed around the vehicle to allow it to proceed in the best manner possible (this is particularly applicable to vehicles with 5 or more wheel assemblies) used in outback or military service etc. where survival is critical.

Each wheel assembly on a vehicle is identical, hence any remaining good ones can be fitted at any connection point (referred to here as a vector connection point) and once plugged in there it will begin to perform exactly the same as the damaged/faulty one which was removed.

Each wheel assembly module on a vehicle is typically the same, and each one has a drive motor and at least one steering motor, i.e. on a conventional vehicle there is only one or two steering mechanisms and losing it means you cannot proceed. With the present system, because each wheel assembly has its own steering motor system, it allows the master vector profile to be reconfigured such that once again the vehicle can be steered even though it may have lost steering on one or more of its wheel assemblies (which can be locked to a fixed setting, and the master control computer informed of it) thus allowing the vehicle to proceed.

The main energy feed (electric cable) to each wheel assembly passes via one or more circuit breakers and one or more reverse protection devices (diode etc.) which acts to allow electrical energy to flow from the main

structural frame of the vehicle out to each wheel assembly, but not the opposite, i.e. should a fault develop on any wheel assembly or in the main structural frame, then it cannot effect the batteries in each of the wheel assemblies hence guaranteeing that the vehicle will remain operational. Again, features such as these could be of particular value in outback or military service where survival is critical.

Similarly the main control computer has its own battery and is protected in a similar manner to the wheel assemblies. In addition, the main control computer can be duplicate and triplicate for the ultimate in reliability.

In the case of a vehicle travelling around a curve, it is important that the innermost wheels are at a different angle to that of the outermost wheels. When the radius of the circle is large, then the error with a conventional vehicle is relatively minor. However when the vehicle is turning in a tight circle then there is considerable error and as a consequence tyre scrubbing and loss of traction waste of energy and rubber.

The vector profile allows the master control computer to control each of the wheel assemblies to point their wheel at exactly the right angle to ensure that it is always tangential to the radius at that wheel. Also, the speed of the inner wheels (smaller turning radius is also less than the outer wheels (larger turning radius) and this is also exactly controlled by the vector profile.

Multi-wheel steering, i.e. since the direction and speed of each wheel assembly is controlled by the vector profile it means that the vehicle will, as a standard feature, have all wheel steering irrespective of the number of wheels.

With irregular shaped multi-wheel vehicles and/or vehicles with wheel assemblies underneath the vehicle and/or exterior to it, or in a mix of both, the vector profile in the master control computer will output the correct vector data to each wheel assembly to allow all of the wheels to be controlled exactly in both speed and direction and so perform to their very best.

Another of the drawbacks of most vehicles (from a manufacturing, spares and maintenance perspective) is that typically no two wheel assemblies

on a vehicle are the same, i.e. some are steered, some are not, some are powered, some are not, some will only fit on one side and not the other.

The modular multi-function vehicle according to the invention overcomes this by using exactly the same wheel assemblies in all positions. Also, they can have "quick release" type mounting allowing a replacement to be fitted in minutes.

From a maintenance perspective, it has additional advantages since now there is only one type of module per vehicle. Hence, spares holding is reduced. Also, it makes for efficient repair of the wheel assemblies on a quasi production line basis, rather than individual repair all over the country, i.e. a reconditioned module is fitted, and the faulty module sent to a major repair center, with all the computer diagnostic equipment to allow quick efficient low cost repair.

With a conventional vehicle, should one wheel lose traction (due to soft ground, oily surface etc.) then not only has traction been lost on one wheel, but possible worse is that this has reduced the power going to the remaining wheels that do have good traction. Certainly vehicles fitted with "differential lock" will, after a short delay, lock and overcome the problem. However that wheel will still spin for at least a fraction of a wheel rotation before the lock acts.

Alternatively, consider a conventional vehicle fitted with ABS systems which act nearly instantaneously, but then tries to correct the problem (of a spinning wheel) by applying a brake action to that wheel, hence wasting energy and brake pad material, i.e. at best the "differential lock" and ABS systems either act too late, or waste energy and brake pads or both.

The present invention overcomes this problem with one simple solution total vector control. Here the speed of each wheel is precisely controlled, and is forced to turn at the correct speed irrespective of whether it or other wheels are slipping, it does not matter.

In the case of a conventional vehicle which is braking, i.e. with negative acceleration travelling in a straight line. Here the kinetic energy of the vehicle and of some of its rotating parts is being wasted, (some electric vehicles

etc. part of the energy is stored) in an effort to reduce the speed of the vehicle.

Should one wheel lose traction (due to soft ground, oily surface etc.), that wheel will tend to lock up and it will then depend on the skill of the driver as to what happens, but at best it will almost certainly mean that the driver will have to reduce the braking effect on all wheels in an effort to stop that wheel from skidding or locking.

Alternatively, a conventional vehicle fitted with ABS systems which acts nearly instantaneously will tend to correct the problem (of a skidding or locking wheel) by reducing the braking action on that wheel, hence causing it to stop skidding or unlock etc. However, it does not act till it senses that a particular wheel is starting to skid (or at least, on the verge or it etc.), i.e. at best the ABS systems acts later than desirable.

The present invention, with total vector control has the answer. Here each wheel decreases its speed at exactly the correct rate so as to achieve the desired deceleration due to the braking effect of the wheel motor which converts the kinetic energy to electrical energy which is stored in the batteries. Inherent in this is the conservation of a significant percentage of the kinetic energy which is stored back into batteries.

And should one (or more) wheels lose traction (due to soft ground, oily surface etc.), it does not reduce the braking effect available to the remaining wheels even for an instant.

The total vector controls the speed of each wheel instant by instant so that it is forced to turn at the correct speed irrespective of whether it or other wheels are slipping, its does not matter.

Consider the case of a conventional vehicle travelling around a curve, i.e. the arc of a circle. Then the normal differential action allows the wheel closer to the center of the circle to turn at a slower rate than the wheel further from the center of the circle. This has sometimes been referred to as Passive Differential action, i.e. what is easiest goes, the decision as to the relative speed of the wheels, is passively left to the wheels to decide. However provided neither wheel starts to slip, then it works efficiently and well.

However consider what happens should one wheel loses traction (due to soft soil, oily surface etc.), then quite literally whichever of the wheels can turn easiest, does in fact that, i.e. the wheel with poor traction starts to spin which again means that not only have we lost traction on one wheel, but possible worse, is that it reduces the power going to the remaining wheels with good traction, i.e. in a conventional vehicle travelling around a curve the wheels are typically not forced to turn at different speeds by anything in the vehicle, rather it is the surface of the ground on which they run which controls their relative speed of rotation. Hence, should one wheel hit soft soil or an oily surface (and the torque applied to that wheel is sufficient), then it will start to spin. The normal solution to this problem, in a conventional vehicle is to fit a "limited slip differential" which will "lock" and this may be a momentary help in getting through this soft soil etc., but now we have a vehicle which is trying to turn through an arc of a circle, yet 2 of its wheels (at different distances from the center of the circle) are locked together and turning at the same speed. Hence the vehicle is unstable, and will tend to flick around or control in some other unpredictable manner until the differential unlocks.

In the present invention, the motor on each wheel applies the correct torque to that wheel, such that it is forced to rotate at the correct speed. That speed depends on the distance of the wheel from the center of the circle.

The main structural frame may be specially constructed for use, as part of this vehicle, or may be the structural frame of a building, the structural frame of say a piece of mining equipment, of an aircraft, or train or farm equipment, or other vehicles etc. which on a temporary or permanent basis, will attach the wheel assemblies and the associated computers, and software/firmware, operator or other controls, computer data control network, and sources of electrical energy etc. (Note in some cases some items may already exist, i.e. a source of electrical energy). The invention is also applicable to use with say seasonal equipment, i.e. a set of say 12 wheel assemblies, and associated computers etc. may be fitted to say a cultivator for soil preparation, then the set (or part of that set) may be fitted to combine harvester etc.

Flexibility is one among many features of this invention. Consider again the example above. During the major soil preparation, the cultivator may have say 12 wheel assemblies fitted, then once it is only required for lighter work, say 7 could be swapped to a harvester or other plant or equipment as required.

Manoeuverability is another among many features of this invention. The wheel assemblies typically feature full 360° of steering hence a car can simply drive sideways (crab style) into a parking space, thus allowing expensive city parking space to be more efficiently used, possibly by the concept of vehicle only parking spaces, and or parking stations, i.e. crab only parking.

The vehicles use electric traction and other motors, thus another feature of this invention is very low or zero pollution due to the use of solar cells, and fuel cells as the preferred energy source. Another reason for vehicle only parking.

The vehicle of this invention, features computer control of the vectoring of each wheel (i.e. both in speed and direction). Both the speed and direction of each wheel being individually controlled to within very close limits, thus provides excellence in road holding, handling, traction and maneuverability, i.e. when turning sharply, it may be necessary for each wheel to point to a different heading, and turn at a different speed, this is easy for the vehicle where each wheel assembly is under the control of the master control computers. Hence no more, or much reduced, squealing tyres and wasted rubber.

Reliability is another of the features of the vehicle described in this invention. Here each wheel assembly contains (among other items) a traction motor, one or more steering motors, batteries (or other energy storage devices). Hence if say one traction motor failed, the vehicle can still proceed.

The invention relates to a vehicle constructed from a Main Structural Frame (MSF) to which are attached a number of typically identical wheel assembly modules referred to as Vector Wheel Modules (VWMs) which are uniquely controlled from a Master Control Computer (MCC) and its software/firmware including the vector control software/firmware in the Main Structural Frame (MSF) in such a manner to allow the vehicle to move, turn,

travel etc. as required.

Typically each VWM will be connected to the MSF by a electrical linkage which can include a quick release mechanism and one or more electrical cables and/or fiber optic cables which typically will have plugs/sockets or other means to allow rapid disconnection and reconnection.

Each of the VWMs can be sent different vector data by the MCC. Hence it is possible to force the wheel in each VWM to turn at a different speed and steer at a different angle to that of any other VWM on that vehicle. Typically the vector data sent to each VWM is unique. The wheel speed specified and the steering angle specified for that wheel, have been calculated by the vector control software/firmware which runs in the master control computer.

The polyphase traction motor used in each VWM can force that VWM's wheel to quite accurately rotate at the specified speed in either direction and over a considerable range of RPMs.

The steering motor used in each VWM can force that VWM's wheel to accurately steer at the angle specified for that VWM. Also, it can do this through a full 360°, and that some implementations allow for multiple revolutions. Other implementations provide for typically more than 180°, but due to the speed being controlled equally well in both clockwise and counter-clockwise this still provides good flexibility.

Typically the vector control data from the MCC is fed via wire or cables or fiber optic cables to each of the VMWs, all of which typically have a unique address, i.e. the vector control system may be considered as a "steer by wire" system.

By using a polyphase traction motor (typically a polyphase induction motor) in each VWM, the wheel speed can be quite accurately controlled by controlling the frequency of the alternating currents supplied to the polyphase traction motor.

Each VWM, in the embodiment, has a polyphase inverter which supplies the polyphase alternating current the required frequency to the polyphase traction motor. The polyphase inverter is located immediately

adjacent to the polyphase traction motor, and can be mounted within the polyphase traction motor.

Typically each VWM contains at least one significant energy storage device/battery which is located immediately adjacent to the polyphase inverter which supplies the polyphase current tot he polyphase traction motor.

The energy storage devices/batteries have low internal impedance, and are capable of powering the VWM for at least a few seconds but more commonly be able to power it for some minutes or hours. The majority of the vehicles energy storage capability may be located within the VWM.

The length of the electrical conductors between the polyphase traction motor and its polyphase inverter and the energy storage device/battery is short and typically is a small fraction of the wave length of the frequency component which if radiated, could constitute an EMC problem. Filters, inductors, capacitors etc. can be inserted in the main DC bus where it enters the VWM. Fuses, circuit breakers and diodes can be fitted to the DC bus where it enters the VWM so as to prevent short circuit or other failures in the MSF or other VWMs from affecting the operation of the remaining good VWMs.

The Vector Control Software/firmware treats the vehicle movements as travelling an arc of a circle. The radius of the circle is specified by the position of the steering transducer (i.e. the steering wheel, control lever, etc.) which feeds information to the Master Control Computer (MCC) to specify the radius of the circle, under the control of the operator.

The magnitude of the speed (and its sign) is specified by the speed transducer (i.e. accelerator) which feeds information to the MCC to specify the vehicle's speed, under the control of the operator. From the transducers as described above the Vector Control Software/firmware causes the MCC/micro to send the appropriate data control signals to each VWM to cause it to vector so that the main structural frame of the vehicle moves as required. When the vehicle is remotely or roboticly controlled then the transducers are not used, instead an electronic signal is fed directly to the MCC.

Typically the vector control software/firmware causes each of the

wheels to turn at a speed which is proportional to that VWM's distance from the center of the circle as specified by the steering transducer (item 119 on Figure 10). The vector control software/firmware can cause each of the wheels to steer at an angle such that its wheels are pointing along the tangent of the circle as specified by the steering transducer etc.

The vehicle can use a number of difference sources of electrical energy including solar, fuel cells, and IC engine driven alternators, and the recharging of batteries from mains electricity or other supplies. The vehicle can have solar cells mounted, in or on the roof, bonnet, boot and/or other locations which receive sunlight. The electrical energy provided by the solar cells can be fed in to the Electrical Bus System for distribution, storage, use, etc. The vehicle may use arrays of solar cells, either fixed (i.e. on buildings or other structures) or portable so as to allow them to be set up when and where and as desired.

The solar power can be provided by a detachable solar source (DSS). The detachable solar source can consist of arrays of solar cells, mounted on one, or more, special purpose built trailers, articulated trailers, caravans, etc. which can be towed or otherwise controlled by, either the vehicle, or other vehicles, such that they can move, and/or travel with that vehicle.

The vehicle can use regenerative braking and can have provision for friction braking (typically disc or drum brakes); additionally it may have mechanical wheel lock devices.

During regenerative braking, should a wheel start to slip or skid, the speed of the wheel will only vary by a relatively small percentage from its "synchronous speed". Because as the wheel speed goes below its synchronous speed, the polyphase motor will start to feed energy into the wheel (i.e. the motor will stop acting as an alternator and begin acting as a motor). Note the synchronous speed of the wheel is the synchronous speed of the motor divided by the reduction ratio of the transmission which exits between the motor and its wheel.

The basic method of steering can be with the "Steer by Wire" SBW, but the vehicle may also include a mechanical linkage based steering

mechanism referred to here as mechanical override steering MOS such that if the SBW failed, that the MOS system would be able to control the steering of individual or all VWMs, sufficiently well to significantly reduce the risk of accidents. When the vehicle is operating at say greater than 20KPH, i.e. on a public road etc. that the MOS system will not degrade the operation of the SBW system but still provides a safety backup steering system. When operating at slow speed and tight turns etc. the VWMs are only controlled by the SBW, and that this occurs automatically based on the angle of steer.

Due to the modular self-contained nature of the VWMs, and the simplicity of their interconnection to the Main Structural Frame (MSF) (i.e. a few cables/fiber optic connectors etc.), the use of innovative suspension systems is possible. Also, because the energy storage devices/batteries and the traction motors are located in the VWM and hence the suspension does not have to support their weight, the suspension can be optimised to suit the task for which the vehicle is intended. There is no need for drive shafts Constant Velocity Joints etc. hence the VWM concept is very adaptable, for example to suspensions which allow the height of the MSF above the road or ground to be varied from zero to a meter or even higher should it be required. The height control mechanism would be controllable by the operator in the MSF. This also is of advantage during maintenance in that it will allow VWMs to be removed without the need of lifting devices for the vehicle.

The vehicle can have a motor (item 120 of Figure 10) connected to the steering wheel, and under the control of the Master Control Computer such that the motor simulates some fraction of the average steering torque being exerted by the steering motors. Hence the steering wheel will simulate the feeling experienced in a conventional vehicle. Strain gauges (item 109 of Figure 6B) or similar devices can be fitted to each of the plates on which the steering motors mount, so as to sense the torque exerted by each of the steering motors, this data is fed back to the Master Control Computer so that it can drive the motor on the steering column so as to provide the correct simulation to the operator. Also at power up or as otherwise specified the Master Control Computer will

typically contain software/firmware such as to perform a self test on the steering system so as to verify it is functional and also to measure the degree of slop in the steering system. That also in a vehicle with the MOS option fitted it will also check out the mechanical linkages etc. in the MOS system in addition to the components of the steer by wire system.

It should be appreciated that various other changes and modifications can be made to the embodiments described without departing from the spirit and scope of the invention.

CLAIMS:

1. A wheel assembly which has a ground engageable wheel, a first drive means to rotate the wheel, a second drive means to steer the wheel, an energy storage device to at least partially supply the drive means, and a attachment means to attach the wheel assembly to a vehicle.

2. The assembly of claim 1, wherein the energy storage device comprises at least one battery.

3. The assembly of claim 2, wherein the first drive means and the second drive means are controlled by computing means.

4. The assembly of claim 3, wherein the first drive means and the second drive means are electric motors.

5. The assembly of claim 4, wherein the wheel, the first drive means, and the energy storage device are supported on a first support which can pivot relative to a second support, the second support being attachable to a vehicle, the second drive means being a steering motor which functions to pivot the first support relative to the second support.

6. A vehicle having at least one wheel assembly of claim 1.

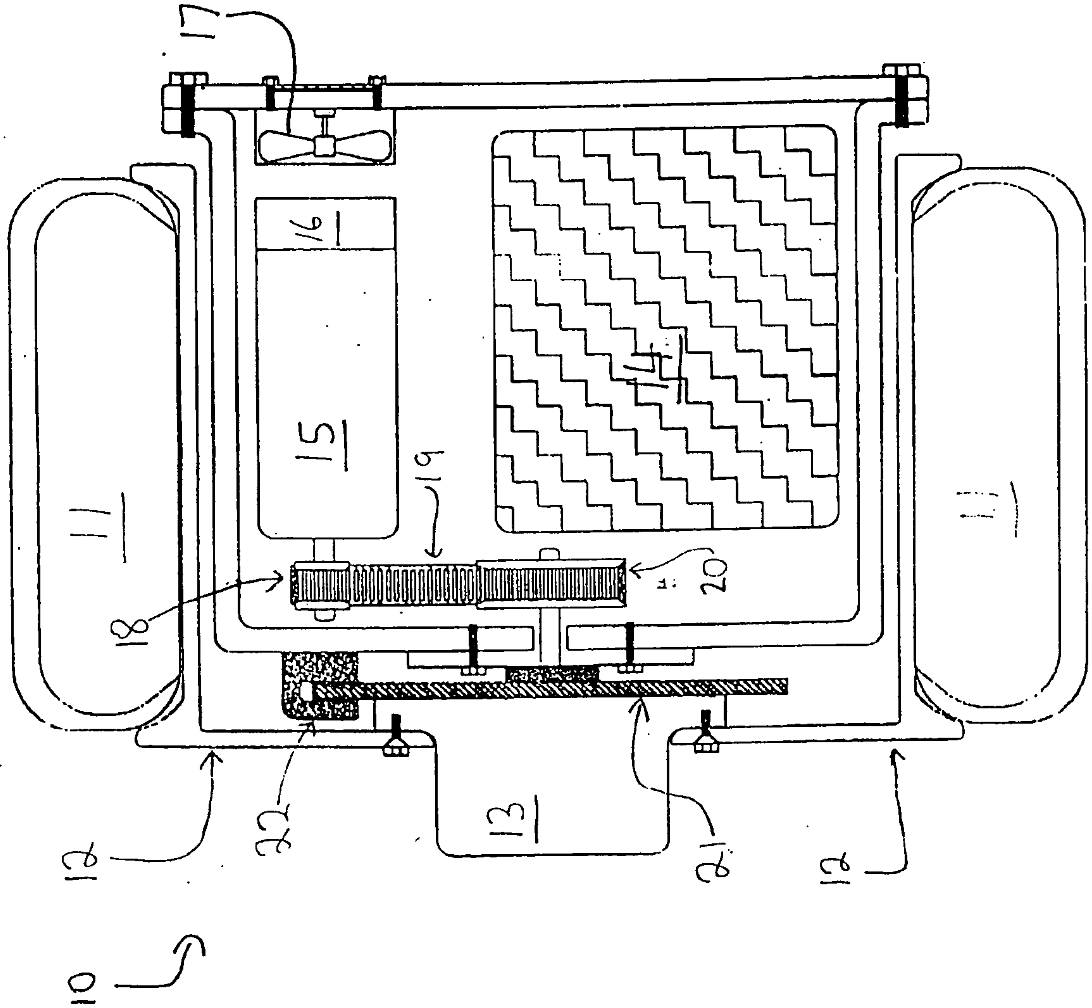
7. The vehicle of claim 6, having a plurality of said wheel assemblies, each wheel assembly having its first drive means and second drive means controlled by a master control computer in the vehicle.

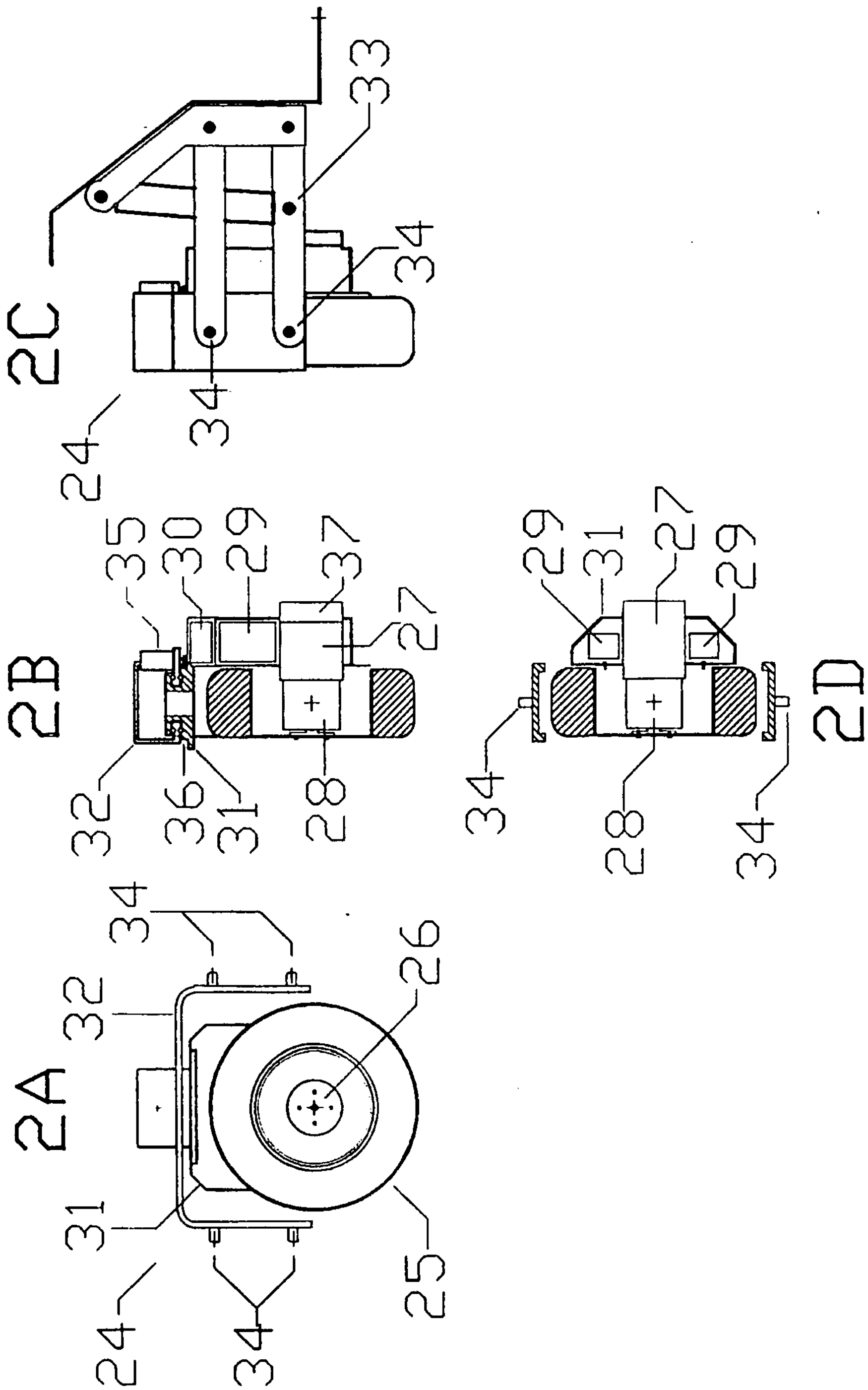
8. The vehicle of claim 7, wherein each wheel assembly is attached to a suspension, and each wheel is steered by control of the second drive means in each wheel assembly only and not by a mechanical steering link.

9. The vehicle of claim 7, wherein a mechanical steering override is operatively associated with at least some of the wheel assemblies to allow mechanical steering should the second drive means fail.

10. The assembly of claim 7 wherein the master control computer controls the pivoting of the wheel in each wheel assembly and the speed of rotation of the wheel in each wheel assembly, the master control computer processing signals from various sensors to provide real time specification of speed and direction of each wheel assembly

FIG. 1

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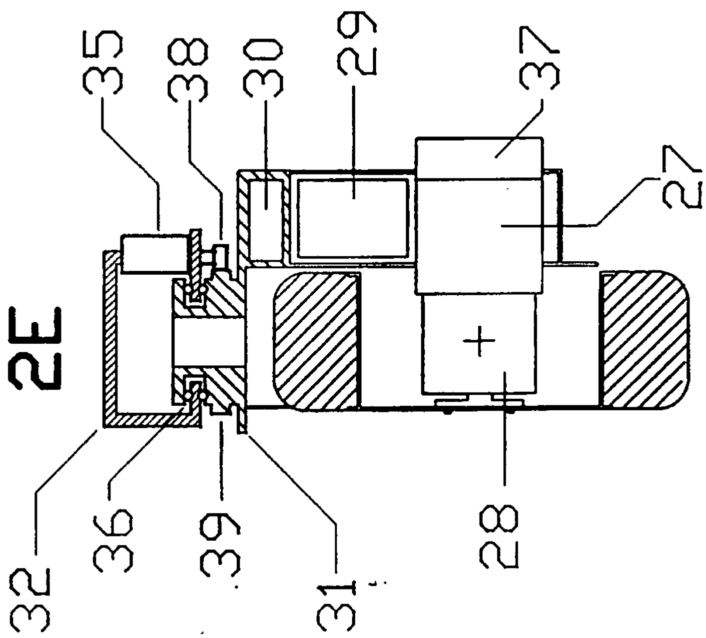

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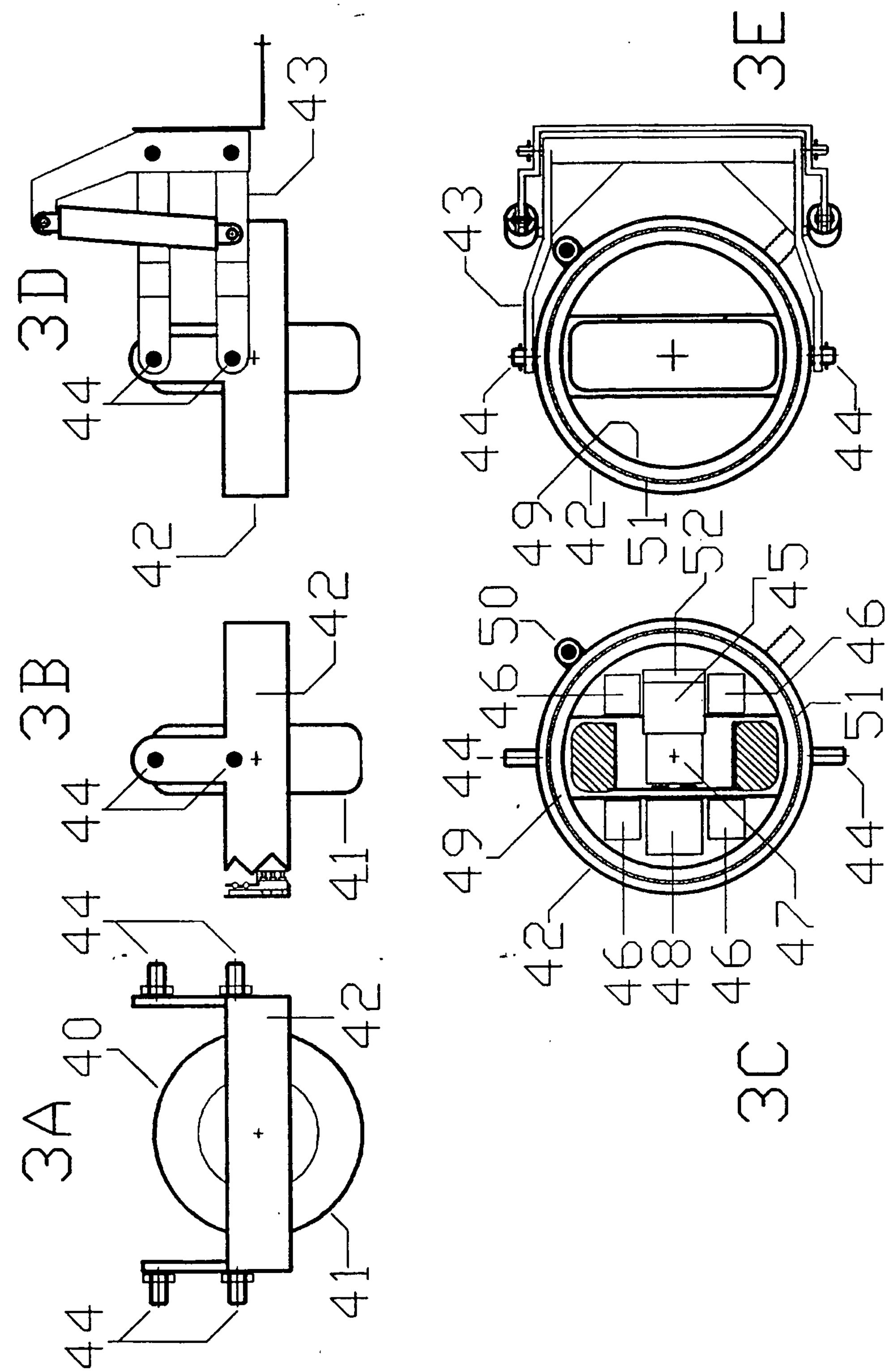
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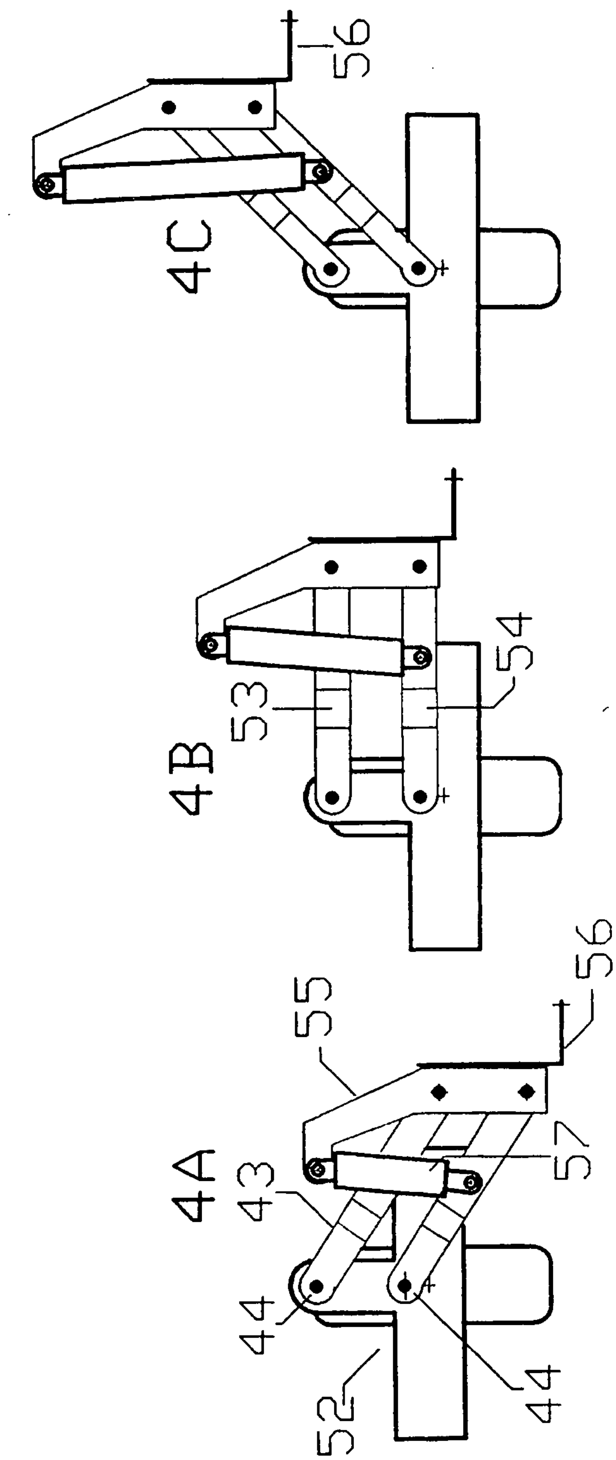

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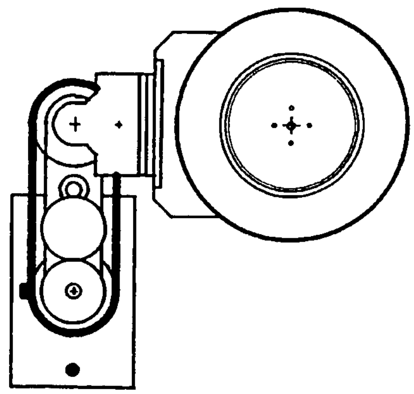

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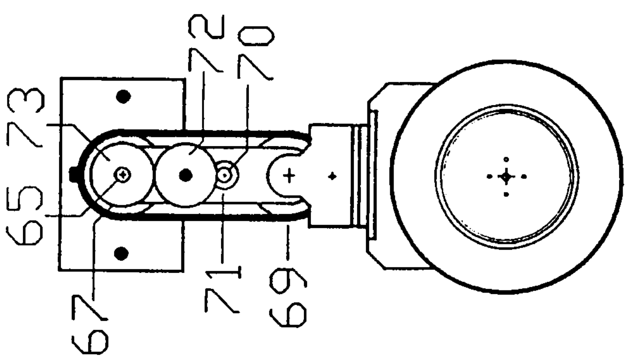

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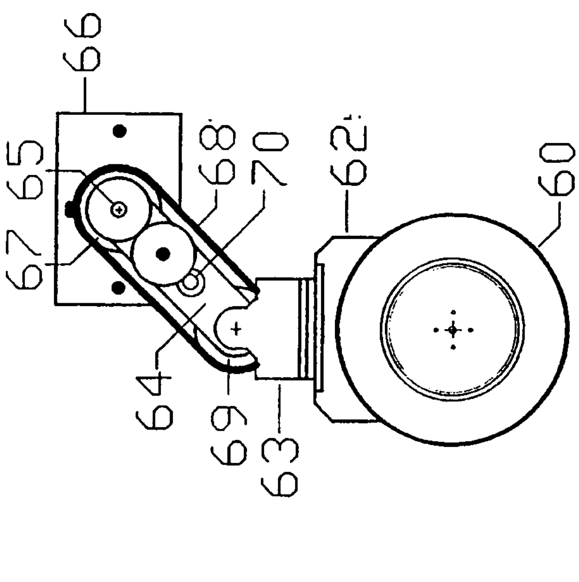

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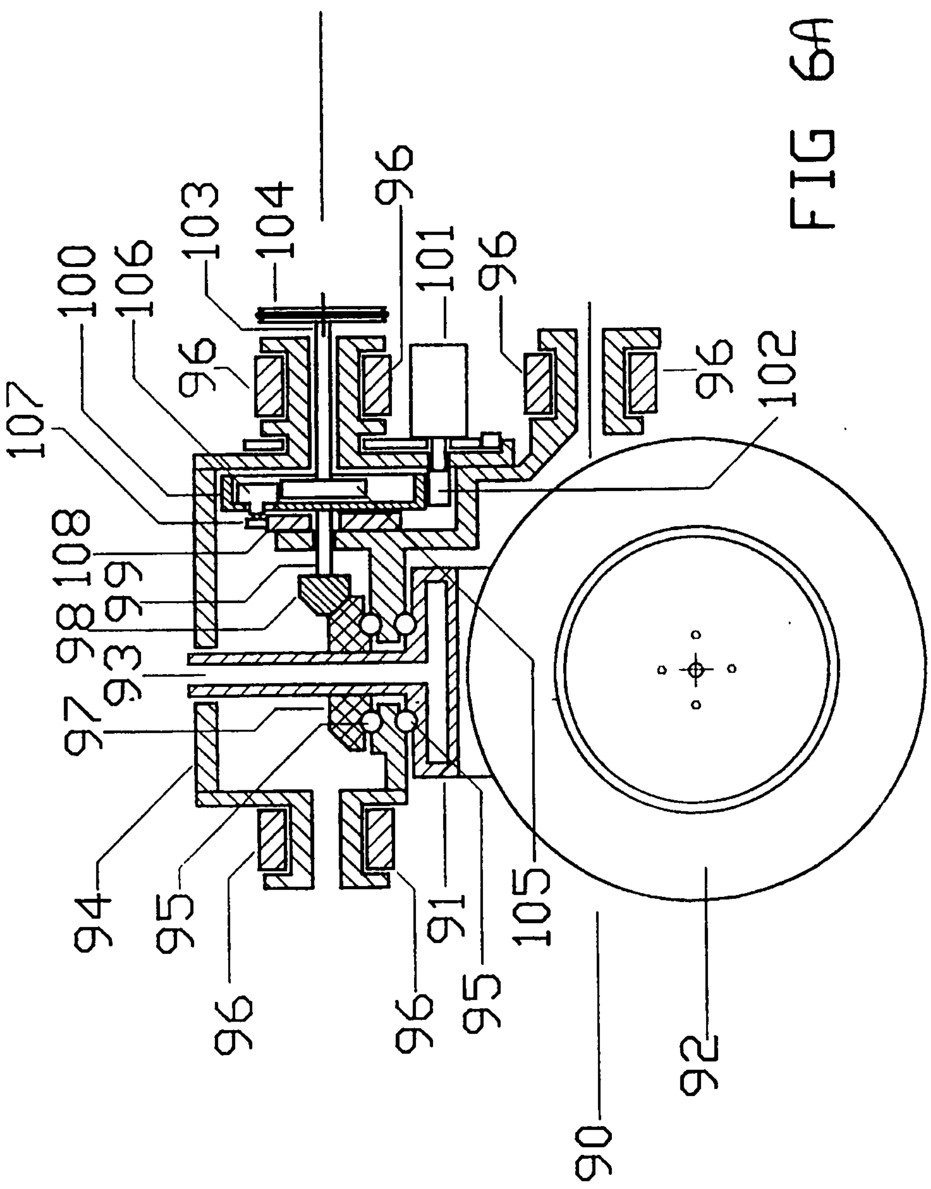

FIG 6A

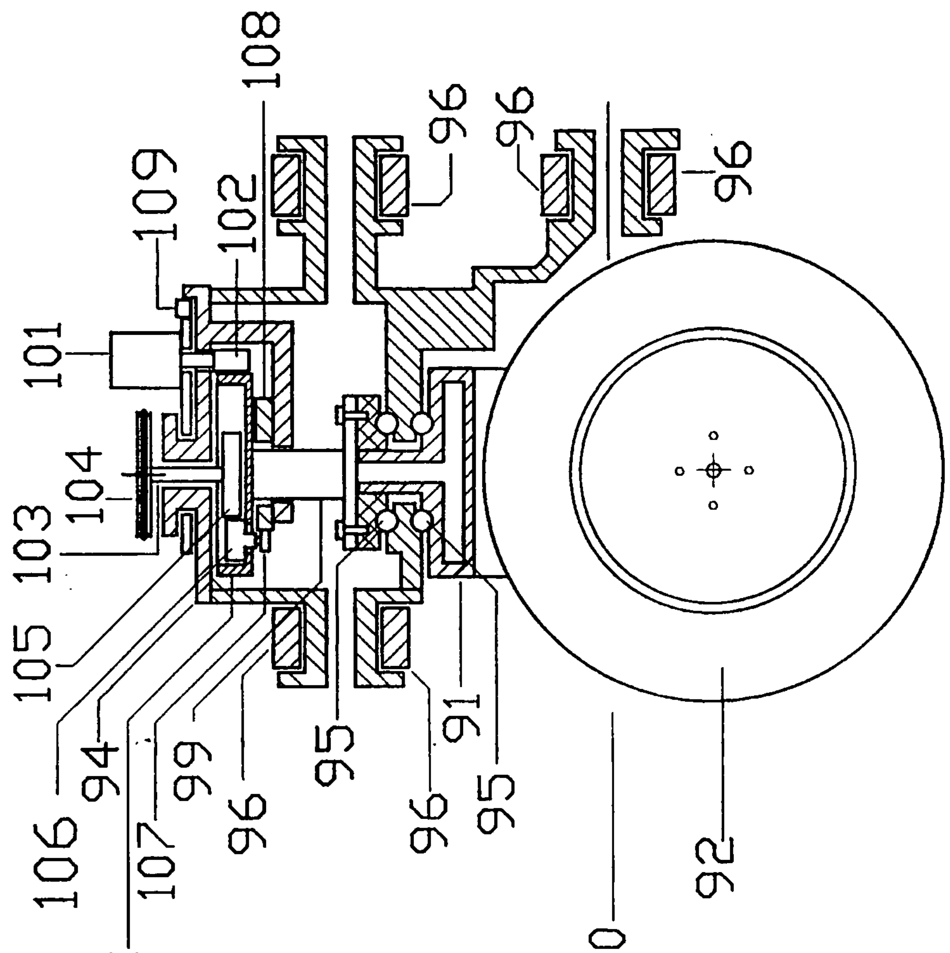
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FIG 6B

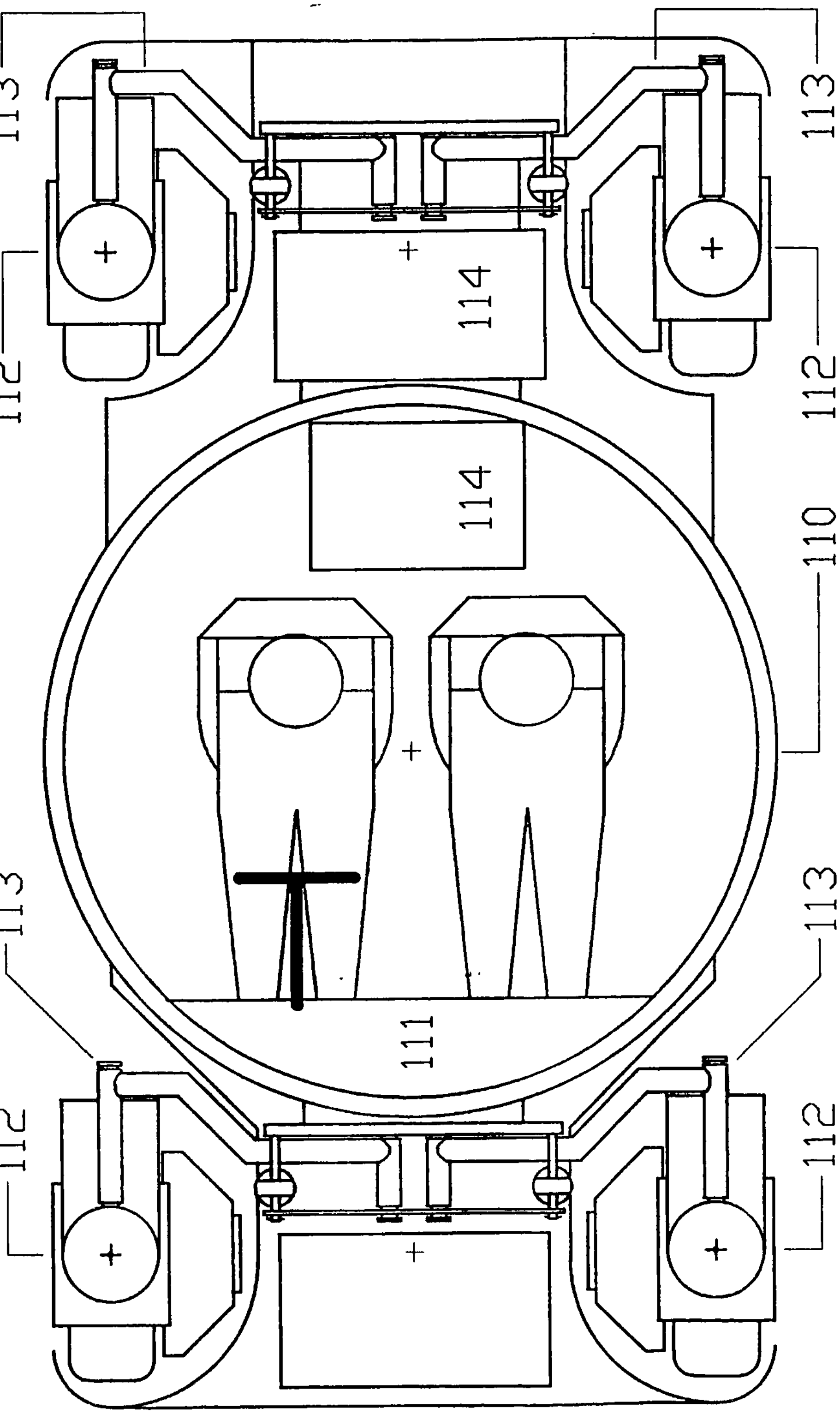

FIG 7

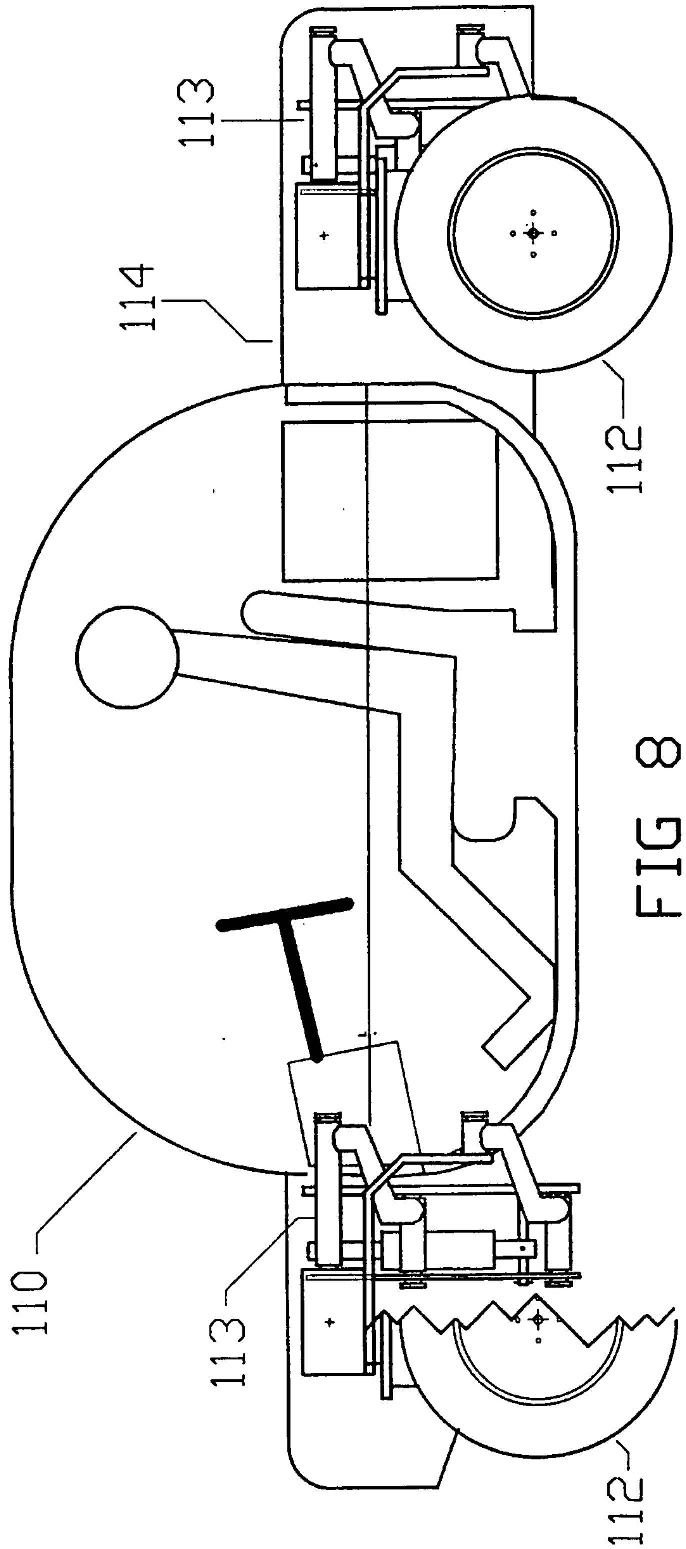

FIG 8

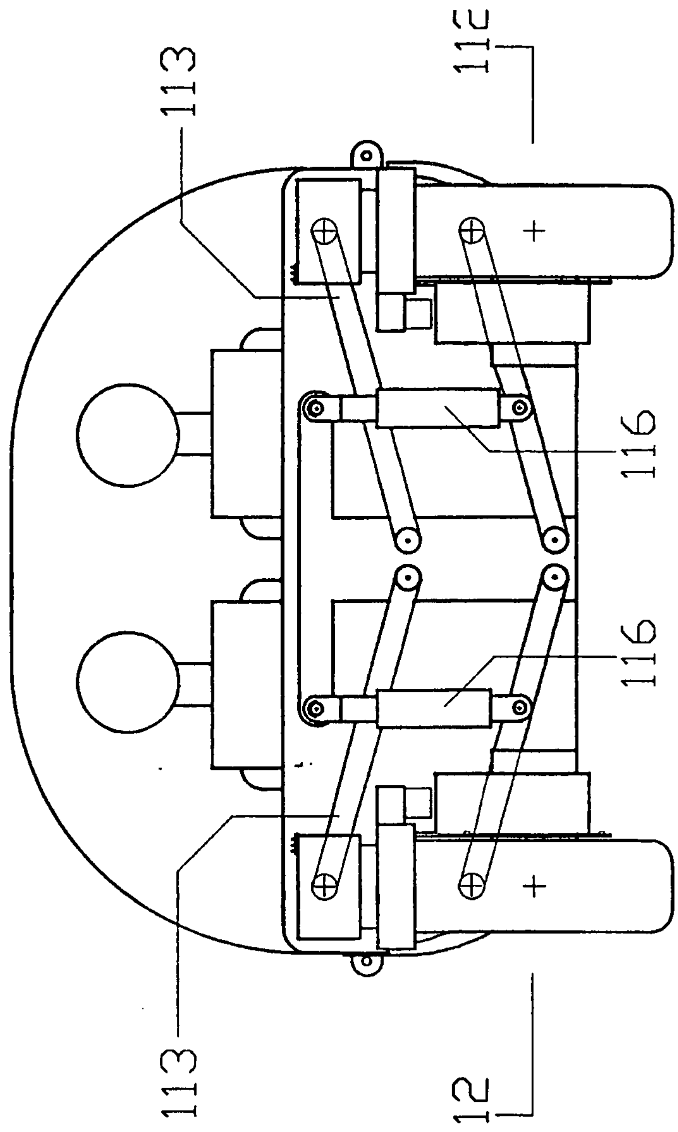

FIG 9

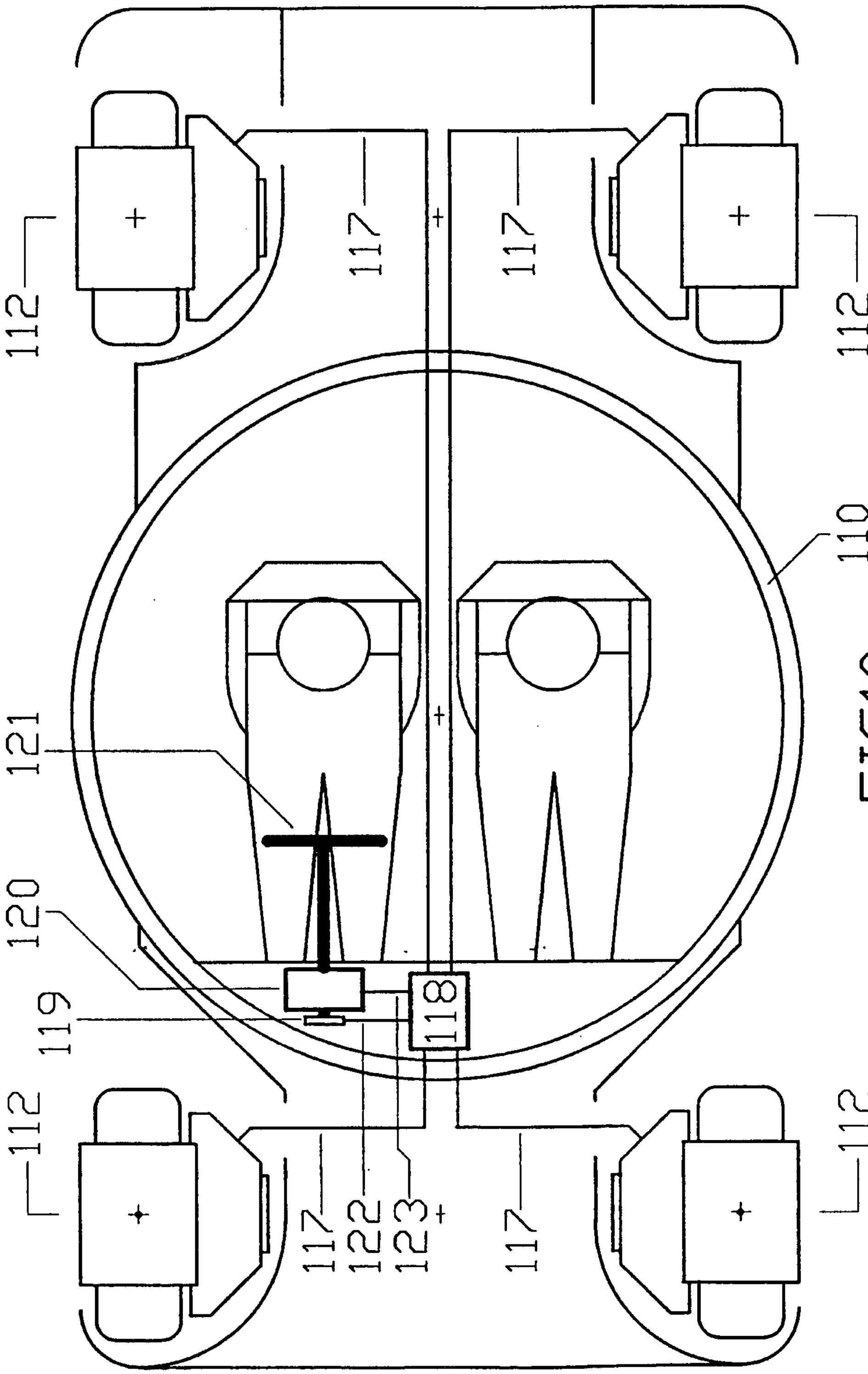

FIG10

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 97/00746

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: B60G 7/00 25/00 B60K 1/02 1/04 7/00 17/356 B60L 7/00 7/14 11/18 15/08 15/30 15/36 B62D 5/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC B60L 11/18 B60K 1/02 1/04 7/00 17/356

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
U.S.P.T.O. & IBM Patent Server [wheel; AND steer; AND batt:]

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2269145 A (HIGGINS) 2 February 1994 See the Abstract	1
A	GB 2224984 A (VAUSE) 23 May 1990 See the Abstract	1
A	GB 2123362 A (WHEELPOWER LIMITED) 1 February 1984 See the abstract	1

☐ Further documents are listed in the continuation of Box C

☐ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 February 1998	13 FEB 1998

Name and mailing address of the ISA/AU	Authorized officer
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